Journal of the Nigerian Association of Mathematical Physics
Volume33,(*January, 2016*), pp 407 – 416
© J. of NAMP

Design of Oil Palm Residues Briquette Making Machine

Onochie Uche Paul[1], *Obanor Albert*[2] *andAliu Sufianu Adeiza*[3]

[1]**National Centre for Energy and Environment, Energy Commission of Nigeria, University of Benin, Benin City, Nigeria**
[2,3]**Department of Mechanical Engineering, University of Benin, Benin City, Nigeria.**

Abstract

A briquette is a block of compressed combustible energy carrier suitable for heating. Briquettes are made from waste materials such as old newspaper, oil palm residues, sawmill wastes etc. They are largely used as fuel instead of charcoal, firewood or coal. The burning of briquettes depends on the materials used for making them. Briquettes are largely combustible materials made from loose or low density wastes but compressed together into a solid.Essentially, this paper focuses on the design of a screw press briquette making machine using the principles of engineering designto design the essential components. The machine isdesigned to produce high density and high quality briquettes of about 70mm diameter from oil palm residues which can be used for domestic and industrial heating purposes such as generating steam to power turbines in steam power stations. This will serve as an alternative and reduce the pressure on the use of fossil fuel for power generation.

Keywords: Briquette Machine, Design Analysis, Oil Palm Residues, Briquette

Nomenclature

N_1 = *Speed of the electric motor*
N_2 = *Speed of the screw shaft (rev/min)*
d_1 = *Diameter of electric motor pulley*
d_2 = *Diameter of shaft pulley*
T = *Torque of the electric motor shaft pulley*
ω = *Angular velocity of the electric motor shaft*
F = *Extrusion force*
A = *Cross-sectional area of the conveyor shaft*
r_1 = *Radius of driving pulley*
P = *Power of electric motor*
T_C = *Centrifugal tension*
T_1 = *Tension in the tight side of the belt*
T_2 = *Tension in the slack side of the belt*
T_t = *Total tension in the belt*
σ = *Maximum allowable tension stress of belt*
d = *Diameter of conveyor shaft*
l = *Screw pitch*
m = *Mass per meter length of belt*
V = *Linear velocity of belt*
T_e = *Twisting moment*
τ = *Shear stress*
W_s = *Weight of shaft*
ρ = *Density of mild steel shaft*

.

1.0 Introduction

The combination of growing energy demands, inadequate power supply due to increase in gas price and pipeline vandalism,

Corresponding author: Onochie Uche Paul, E-mail:onochieuche@yahoo.com, Tel.: +2348023778718

and concern over the impacts of carbon emissions associated with the combustion of fossil fuels have increased pressure to utilise renewable energy resources. In Nigeria, the oil palm mills generate substantial amounts of biomass waste. The waste material is obtained after the Fresh Fruit Bunches (FFB) undergoes various stages of processing. The waste product or mill residues consist of Palm Kernel Shell (PKS), Palm Fibre (PF) and Empty Fruit Bunches (EFB), which can be utilized for energy recovery purposes.

In **[1],** it was established that NIFOR, could generate the power requirements of their mill and environs using these residues. However, in their raw form, these residues generally do not possess High Heating Values (HHV) due to the high moisture content **[2]** compared to more established solid fuels like coal. The storage conditions at the mill can sometimes make it worse for the already wet residues and in its loose form, handling and transportation to other locations are also not favourable. Due to the abundance of supply, not much effort is made by the mills to improve the condition of their fuel. The practice of energy recovery in palm oil mills is therefore, a non-efficient one, leaving lots of room for improvement.

Oil palm residues are used in their crude form for heating during cooking**[3].** However it burns with a lot of smoke due to its organic content. The effect of such smoke to health cannot be over emphasized. Even in such cases, most of their energy content is not used up (incomplete combustion) as these residues are common sight at ash dumps. Briquetting would remove these inadequacies and make for efficient and sustainable use of these residues.

A briquette is a block of compressed combustible energy carrier suitable for heating. Briquettes are made from waste materials such as old newspaper, oil palm residue, sawmill wastes etc. They are largely used as fuel instead of charcoal, firewood or coal. The burning of briquettes depends on the materials used for making them. Briquettes are largely combustible materials made from loose or low density wastes but compressed together into a solid. The compression leads to a product of higher bulk density, uniform size and shape**[4]**.

Also, since the raw materials for briquettes are loose and low density, the production of briquettes will be profitable and economical if situated close to sources of raw materials. The compaction of the briquettes should be able to withstand long distance transportation, multiple handling and long-time storage.At the beginning of 19th century, briquettes were made with tar or resins as the binders, but could not gain importance at that time due to relatively higher costs compared to wood and charcoal. They re-emerged in the 1950s when millions of tons of briquettes were produced and consumed**[5].** The interest has since been on the increase.Essentially, the aim of this paper is to design a screw press briquette making machine that is capable of producing high density and high quality briquettes of about 70mm diameter from oil palm residueswhich can be used for domestic and industrial heating purposes such asgenerating steamto power the turbines in the steam power stations. This will serve as an alternative and reduce the need for the use of fossil fuel for power generation.

2.0 Methodology

2.1 Design Specification

Design specifications were adopted in creating conceptual designs. The design factors considered were safety, temperature, functionality, cost, manufacturability and assembly, and maintenance. Table 1 highlights the design specifications used.

Table 1: Design specifications adopted in creating conceptual designs.

S/N	Design specification	Basis	Material & rating	Justification
1.	POWER CONSUMPTION	Determines the energy consumption of the machine and its manufacturing cost.	Low speed motor	The operational system of the machine requires low speed motor.
2.	SHAFT	High strength, wear resistant, machine-able and transmission of torque.	Mild steel	Can withstand shear force and compressive force.
3.	PULLEY	Ratio of input to output speed from electric motor to shaft.	Cast iron	Reduction of speed from the electric motor is required for the system operation.
4.	V-BELT	Power transmission	Fibre reinforced rubber	Low speed and high torque operation.
5.	FRAME SUPPORT	Provides rigidity for the machine and prevents failure caused by fatigue.	Mild steel angle bar	ASTM specification.
6.	HOPPER	Residues feeding channel	Mild steel sheet	For strength & weld-ability.
7.	DESIGN LIFE	Life span of the machine	-	Compensation for total cost of the machine and quality of materials used.
8.	MACHINE COST	An overview of the fabrication cost.	Affordable	For Commercialization.
9.	DIE/MOULD	Channel for residues to form into briquettes	Mild steel	Strength and weld-ability

2.2 Design Concept

The design concept is based on the specification outlined in Table 1. An attempt was made to develop three design concepts and their mechanism of operation. A comparison was made and finally, concept three was selected for detailed design analysis due to its comparative advantages over other concepts. Figure 1 and 2 show the isometric and skeletal views of the selected concept.

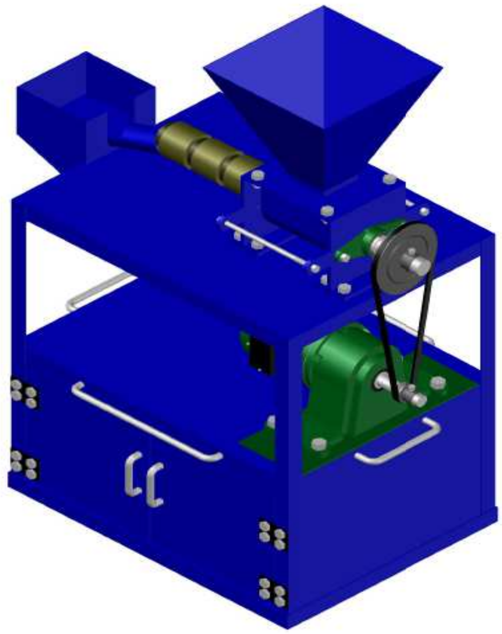
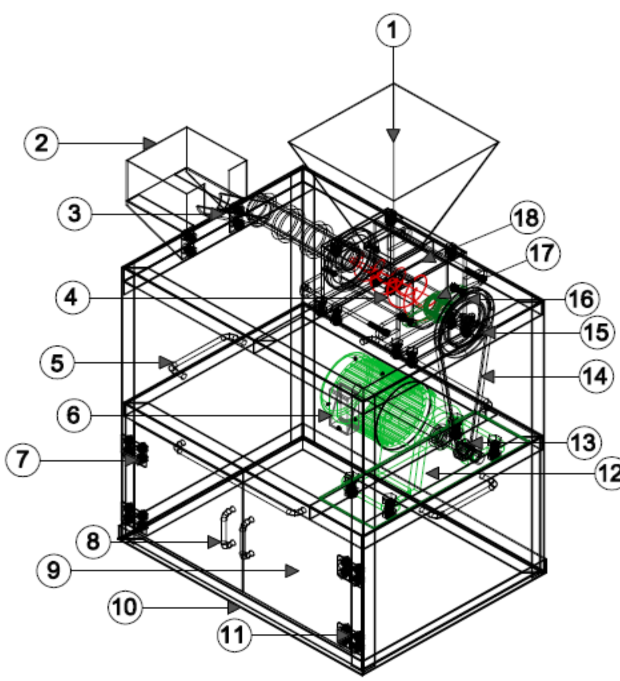


Figure 1: Isometric view of design concept



S/NO.	DESCRIPTION
1.	FEED HOPPER
2.	COLLECTION TRAY
3.	DISCHARGE CHANNEL
4.	SCREW PRESS
5.	CARRIAGE HANDLE
6.	ELECTRIC MOTOR
7.	BOLT AND NUT
8.	DOOR HANDLE
9.	TOOL BOX/SHELF
10.	MACHINE FRAME
11.	DOOR HINGE
12.	MOTOR GEAR SYSTEM
13.	MOTOR PULLEY
14.	DRIVE BELT
15.	SCREW PRESS SHAFT
16.	SCREW PRESS PULLEY
17.	BEARING
18.	PRESS CHAMBER

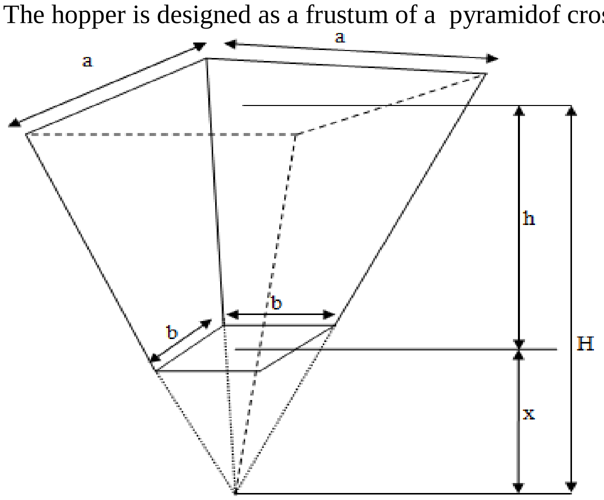
Figure 2: Skeletal view of design

2.3 Design Analysis

Detailed analysis of the concept was carried out to determine the necessary design parameters for selection of the various machine components. This was done in order to avoid failure of the components during the required working life of the machine.

2.3.1 Hopper

The hopper is designed as a frustum of a pyramidof cross-section as shown in Figure 3.



a = inlet length and width of hopper = 350mm
b = outlet length and width of hopper = 80mm
h = height of hopper = 300mm
x = height of the small cone below the frustum
H = height of the pyramid

Figure 3: Diagram of the hopper with square base truncated pyramid

The volume of the hopper,V, was calculated using the equations outlined in **[6]:**

$$V= V_1 - V_2 \quad (1)$$

$$V_1 = (1/3)\, a^2 H = (1/3)\, a^2 (h + x) \quad (2)$$

$$V_2 = (1/3)\, b^2 x \quad (3)$$

Where,
V_1 = volume of the big cone
V_2 = volume of small cone
From Figure 3

$$(h + x) / a = x / b \quad (4)$$

$$x = 88.9\text{mm}$$

Thus from equation (2)
$V_1 = (1/3)\ 350^2 \times 388.9 = 15880083.33\text{mm}^3$
Also from equation (3)
$V_2 = (1/3) \times 80^2 \times 88.9 = 189653.3333\text{mm}^3$
Therefore, the volume of the hopper:
$V = 15880083.33 - 189653.333 = 15690430\text{mm}^3 = 0.001569\text{m}^3$

2.3.2 Extrusion Force

The extrusion force is the force required to extrude one briquette.

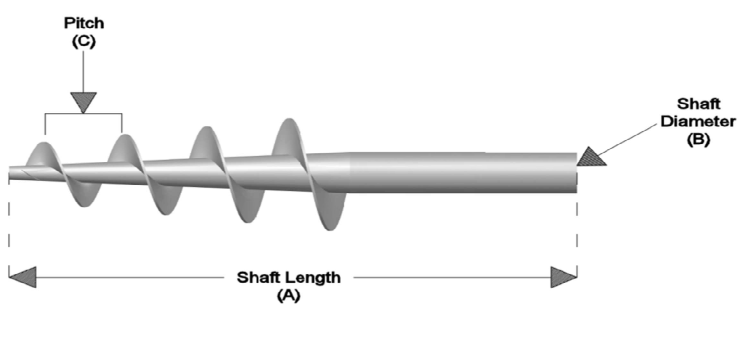


Figure 4: Conveyor Shaft

The shear stress, $\tau_s$acting on the shaft is given by

τ_s= F/A (5)

But A = 1/2πdl (6)

If, d = 25mm

l = 2.5mm

Therefore, the cross sectional area of the conveyor shaft:

$$A= 1/2\times \pi \times 25\times10^{-3}\times 2.5\times10^{-3}= 9.82\times10^{-5}m^2$$

Assumption: The maximum permissible shear stress, τ_s to extrude one briquette = 5MPa

Thus, the extrusion force;

$F = 9.82\times10^{-5}m^2\times 5\times10^6N/m^2= 491N$

2.3.3 Speed of Conveyor Shaft

The conveyor shaft is used for the transmission of torque and bending moment. According to **[7],** the speed of shaft was determined using equation (7).

$N_1/N_2 = d_2/d_1$ (7)

Assumptions:

N_1= 1400rev/min

d_1 = 125mm = 0.125m

d_2 = 250mm = 0.25m

Therefore, speed of screw shaft for briquetting;

$$N_2 = (1400 \times 125)/250= 700\text{rev/min}$$

2.3.4 Power of Electric Motor

$P = T \times \omega$ (8)

But the torque of the motor shaft pulley is:

$T = F \times r_1$ (9)

T = 491 x 0.0625= 30.7Nm

But the angular velocityω is:

$\omega = 2\pi N_1/60$ (10)

$\omega = (2\times\pi\times1400)/60 = 146.6$ rad/s

Therefore, the power of electric motor is:

P = 30.7 x 146.6= 4500.62W

2.3.5 Belt Design

The basis of the belt drive design **[7]**is as follows:

i. Centre – centre distance, x, of pulleys
ii. Length of belt
iii. Area of cross section of belt
iv. Type of belt (V-belt made of reinforced rubber)
v. Mass of belt per meter length
vi. Groove angle
vii. Belt tension
viii. Power transmitted by belt
ix. Number of V – belts required

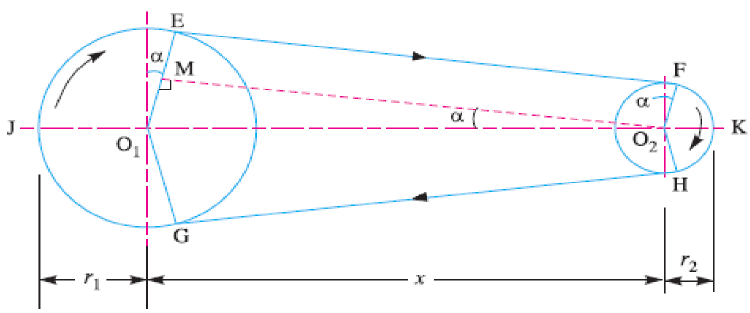


Figure 5: Open Belt Drive **Source:**[7].

i. Centre – to – centre distance, x, between pulley

Note that the centre distance, x, between the two pulleys is twice the diameter of the larger pulley**[7].** Thus, distance between the centres:

$x = 2d_2 = 2(0.25) = 0.5m$

ii. Length of Belt

$$L = \pi/_2\,(0.125 + 0.25) + 2(0.5) + (0.25 - 0.125)^2/\,4(0.5) = 1.71373m$$

$$L = \pi/_2\,(d_1 + d_2) + 2x + (d_2 - d_1)^2/\,4x \qquad (11)$$

iii. Area of cross section of belt

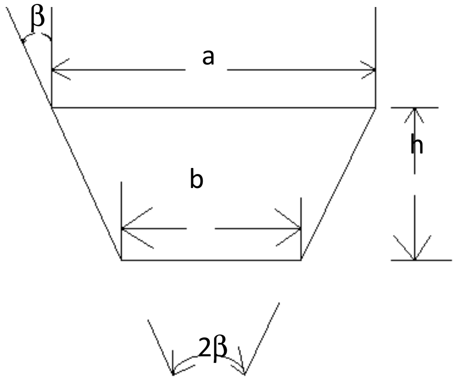


Figure 6: Belt cross section

Area of trapezium, $A = \frac{1}{2}(a + b)\,h$ (12)

Assumption: $a = 12mm = 0.012m$

$b = 6mm = 0.006m$

$h = 10mm = 0.01m$

$A = 9\times10^{-5}m^2$

iv. Mass of the belt per unit length

Density of a double woven reinforced rubber, $d = 1250kg/m^3$ **[7]**

Therefore mass of belt,

m = area × length × density = $9\times10^{-5}\times 1\times 1250 = 0.113kg/m$

v. Grove angle, 2β

Using the trigonometric ratio,

$\tan\beta = (3/10)$,thus $\beta = \tan^{-1}(3/10) = 17^0$ and$2\beta = 34^0$

vi. Angle of contact between the belt and each pulley, α

For an open belt drive,

$$\sin\alpha = \frac{d2 - d1}{2x} \qquad (13)$$

$\alpha = 7.2^0$

Angel of lap on the smaller pulley,

$\theta = 180^0 - 2\alpha$ (14)

$\theta = 165.6^0 = 2.89rad$

vii. Belt tension

Since the belt would continuously runs over the pulleys, therefore, some centrifugal force is caused, whose effect is to increase the tension on both the tight as well as the slack sides.

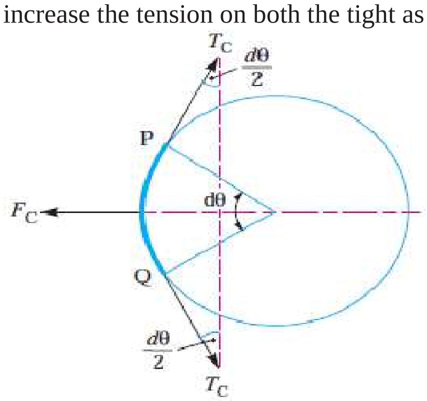


Figure 7: Centrifugal Tension**Source:**[7].

Centrifugal force, $T_C = mv^2$ (15)

But,

Linear Velocity, $V = \pi d_1 N_1/60$ (16)

$V = \pi \times 0.125 \times 1400/60 = 9.164\text{m/s}$

Hence, the centrifugal tension,

$T_C = 0.113 \times 9.164^2 = 9.489\text{N}$

Total tension in the belt, T_t

$T_t = \sigma \times A$ (17)

Where $\sigma = 4.0\text{MN/m}^2$ for rubber [7] and $A = 9\text{x}10^{-5}\text{m}^2$

Hence, the total tension in the belt:

$T_t = 4.0 \times 10^6 \times 9 \times 10^{-5} = 360\text{N}$

Tension in the tight side of belt T_1

$T_1 = T_t - T_C = 350.51\text{N}$

Relationship between T_1 and T_2 for V- belt

$2.3 \log (T_1/T_2) = \mu\theta \operatorname{cosec} \beta$ (18)

Where coefficient of friction for rubber material, $\mu = 0.2$ [7]

Therefore, Tension in the slack side of belt T_2

$T_2 = 48.413\text{N}$

viii. Power transmitted by belt

$P = (T_1 - T_2) V$ (19)

$P = 2768.42\text{W} = 2.768\text{kW}$

ix. Number of V – belts required

Number of V-belt = Total power transmitted / Power transmitted per belt

$= \frac{4.500}{2.768} = 1.6$(1-belt to be used)

2.3.6 Weight of Pulley

Now, let's consider the large pulley as a small cylinder with height, h

Hence, the volume of cylinder, V

$V = \pi (^{d}{}_{2}/_{2})^2 h$ (20)

Assumption: h = 100mm = 0.1m

$d_2 = 250\text{mm} = 0.250\text{m}$

$V = 5 \times 10^{-3}\text{m}^3$

But density of a pulley [7]made of cast iron is 7200kg/m^3

Density = Mass / Volume (21)

Mass = $7200 \times 5 \times 10^{-3} = 36\text{kg}$

Therefore, the weight of the pulley, W_p,

$W_p = mg$ (22)

Where gravity, $g = 9.81\text{m/s}^2$

$W_p = 36 \times 9.81 = 353.16\text{N}$

2.3.7 Design Analysis of the Shaft

Stresses induced in the shaft include; Shear stress due to the transmission of torque, i.e. due to torsional load, bending stress (tensile or compressive) due to the forces acting upon machine element like pulley as well as the weight of the shaft itself, stress due to combined torsional and bending stress and stress due to axial loading [7]:

i. Torque acting on the shaft

For belt drive, the torque was obtained from the equation (23) given

$T = (T_1 - T_2) R$ (23)

$T = 37.8\text{Nm}$

ii. Diameter of Shaft

According to American Society of Mechanical Engineers (ASME) code for the design of transmission shafts with keyway, the maximum permissible shear stress, $\tau_s = 42\text{MPa}$ [7].

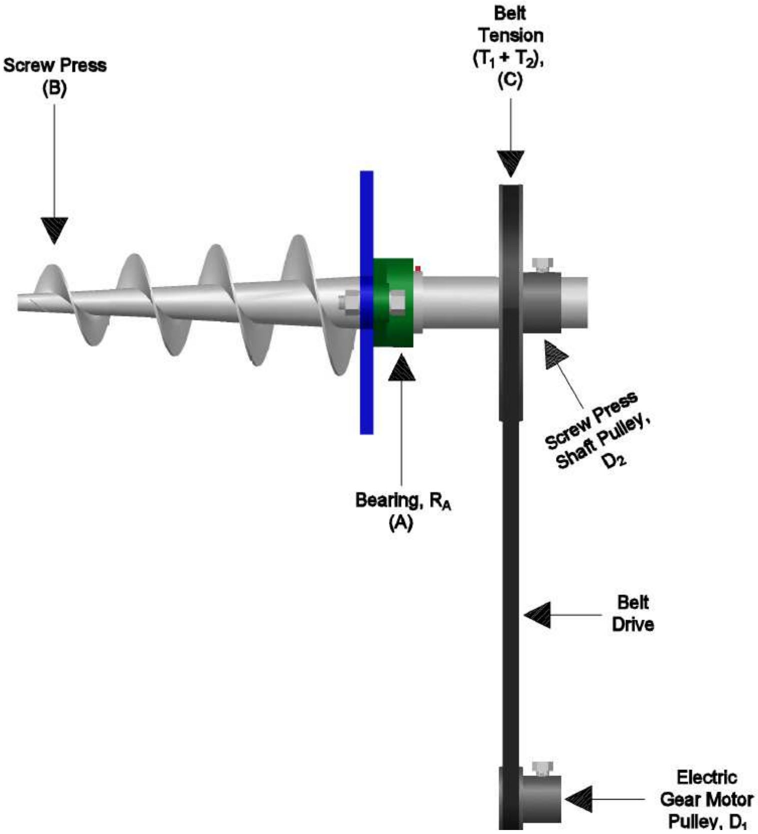


Figure 8: Forces acting on the Shaft

Now, neglecting the weight of shaft, the total vertical load acting on the shaft pulley:

$W = T_1 + T_2$ (24)

$W = 350.51 + 48.413 = 398.923N$

Thus, bending moment of shaft:

$M_b = W \times L$ (25)

Where L = 340mm

Hence,

$M_b = 398.923 \times 340 \times 10^{-3} = 135.6Nm$

Equivalent twisting moment of shaft:

$T_e = \{M_b^2 + T^2\}^{1/2}$ (26)

$T_e = 140.8Nm$

Thus, the diameter of the shaft can be obtained from equation (27).

$T_e = \pi/16 \times \tau \times d^3$ (27)

$d^3 = 0.0257m = 25.7mm$ (25mm to be used)

iii. Weight of Shaft

The shaft is designed as a solid cylinder. Hence the Volume of cylinder (shaft), $V_s = \pi\,(^d/_2)^2 h$

Ifh = 340mm, thus $V_s = \pi\,(^{0.025}/_2)^2 \times 0.34 = 1.6692 \times 10^{-4} m^3$

Mass of screw shaft, M_s = Density of shaft x Volume of shaft

But $\rho = 7850 kg/m^3$ [8]

$M_s = 7850 \text{ X } 1.6692 \times 10^{-4} = 1.31$ kg

Weight of screw shaft, W_s = Mass of shaft x gravity

$W_s = 1.31 \times 9.81 = 12.85N$

iv. Power transmitted by shaft

$P = 2\pi N_2 T/60$ (28)

$P = (2\pi \times 700 \times 140.8) / 60 = 10.32kW$

2.4 The Machine Description

The briquette making machine is a single extrusion die screw press. It consists mainly of driving electric motor, screw shaft, die, belt, pulley and a hopper. During operation, the belt transmits power from the electric motor to the screw shaft through the pulley. The rotating screw shaft takes the raw material from the hopper through the barrel and compresses it against the die which forms a build-up of pressure gradient along the screw. The screw shaft continuously forces the raw materials into the die. At this point, pressure is built up along the screw, thus, the raw materials are compressed in the barrel, and extruded through the die.

3.0 Conclusion

The screw press briquette making machine has been designed to produce 70mm diameter of briquettes.The design is a simple technology which is needed to help in solving energy problems as well as waste management in Nigeria thereby creating a clean, green and healthy environment. The briquette making machine can be easily fabricated with materials sourced locally for ease of maintenance. Medium and small-scale entrepreneurs can be empowered by the Federal Government of Nigeria to make briquettesfrom wastes such as oil palm residues, sawdust, etc. thus reducing the rate of unemployment in Nigeria. Essentially, producing briquettes from briquette making machines will reduce our dependence on fossil fuels (e.g. gas, kerosene, charcoal etc.) for domestic and industrial heating purposes such as generating steam to power turbines in steam power stations. This will serve as an alternative and reduce the need on the use of fossil fuel for power generation.

4.0 Reference

[1] **Onochie U. P (2015):** Project on Evaluating the Potential of Oil Palm Fruit Residues as Biomass Resource for Energy Utilisation: "A Case study of NIFOR" Unpublished M.Eng. Thesis, University of Benin.

[2] **Syamsiro, M., H. Saptoadi and B.H. Tambunan, (2011):**Experimental investigation on combustion of Bio-pellets from Indonesian cocoa pod husk. Asian J. Applied Sci., 4: 712-719.

[3] **Ugwu, K E; Agbo, K E (2011):** *Briquetting of Palm Kernel Shell.* National Centre for Energy Research and Development, University of Nigeria, Nsukka

[4] **Dosunmu, O. O. and Ajayi, A. B., (2002):** Problems and Management of saw mill waste in Lagos. *Proceeding of EPCOWM 2002,* Tunisia, page 271 – 278.

[5] **Lardinios, I. & van del Klundert, A. (1993):** Organic waste: Options for small-scale resource recovery (Urban solid waste series 1). Gouda, the Netherlands: Tool, Amsterdam WASTE Consultants

[6] **Macrae M.F., Kalejaiye A.O., Chima Z.I., Garba G.U., Ademosu M.O., Channon J.B., Mcleish A.S. and Head H.C. (2011):***New General Mathematics for Senior Secondary Schools Book 1.* Pearson Education Limited. 190-191.

[7] **Khurmi R.S. and Gupta J.K. (2005):***A Textbook on Machine Design, Fourteenth Edition*; Eurasia Publishing House (PVT.) Ltd. 2005.

Design of Oil Palm Residues… *Onochie, Obanor and AdeizaJ of NAMP*

[8] **Steel, A.K (2007)**: Product Data Sheet, 304/304L Stainless Steel. p.2. [Online] Availablefrom:http://www.aksteel.com/pdf/markets_products/stainless/austenitic/304_304l_data_sheet.pdf